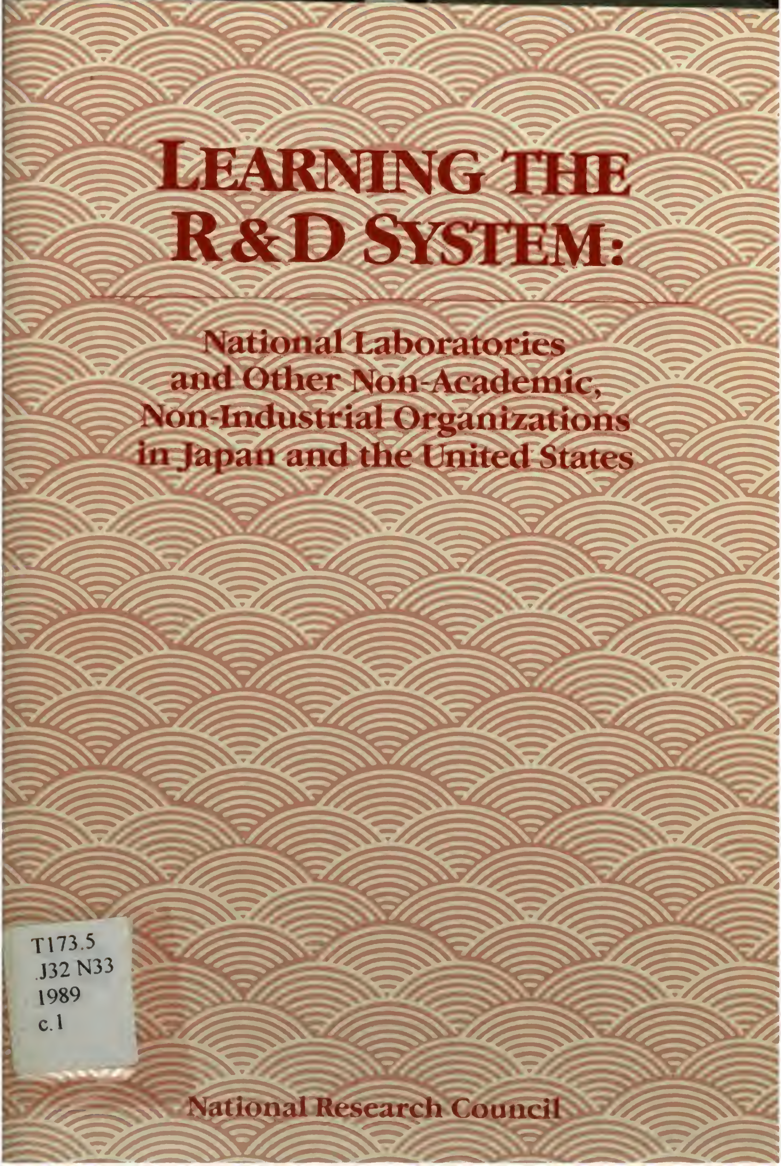

LEARNING THE R & D SYSTEM:

National Laboratories and Other Non-Academic, Non-Industrial Organizations in Japan and the United States

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National Research Council

Learning the R&D System: National Laboratories and Other Non-Academic, Non-Industrial Organizations in Japan and the United States

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Since 1985, the National Academy of Sciences and the National Academy of Engineering have engaged in a series of high-level discussions on advanced technology and the international environment with a counterpart group of Japanese scientists, engineers, and industrialists. One outcome of these discussions was a deepened understanding of the importance of promoting a more balanced two-way flow of people and information between the research and development systems in the two countries. Another result was a broader recognition of the need to address the science and technology policy issues increasingly central to a changing U.S.-Japan relationship. In 1987, the National Research Council, the operating arm of both the National Academy of Sciences and the National Academy of Engineering, authorized first-year funding for a new Office of Japan Affairs (OJA). This newest program element of the Office of International Affairs was formally established in the spring of 1988.

The primary objectives of OJA are to provide a resource to the Academy complex and the broader U.S. science and engineering communities for information on Japanese science and technology; to promote better working relationships between the technical communities in the two countries by developing a process of deepened dialog on issues of mutual concern; and to address policy issues surrounding a changing U.S.-Japan science and technology relationship.

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U.S.-JAPAN DIALOG ON THE WORKING ENVIRONMENT FOR RESEARCH IN NATIONAL LABS AND "BRIDGING" ORGANIZATIONS

Beckman Center

June 5-6, 1989

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Justin Bloom of Technology International assisted with preparations for the meeting and contributed to the discussion.

Preface

The Office of Japan Affairs of the National Research Council is organizing a series of workshops on the differences and similarities in the working environment for research in Japan and the United States with the support of a grant from the U.S.-Japan Foundation. Understanding these differences is essential to American scientists and engineers to improve access to Japan's research system, and to expand mutually beneficial collaboration between the two countries.

The bilateral dialog on "Coexistence in a Technological World: Cooperation and Competition in R&D" consists of three workshops, focusing in turn on universities, bridging organizations, and corporations as research settings. Each workshop brings together senior scientists, engineers, and others involved in and concerned about research and development in the two countries. The second workshop on national labs and other non-academic, non-industrial organizations was held June 5-6, 1989, at the Beckman Center, the West Coast facility of the National Academies of Sciences and Engineering. The discussions focused on "bridges" between national labs and other sectors in electronics and new materials research, on professional associations and consulting organizations, and on the prospects for international collaboration. This report, prepared by the Office of Japan Affairs, highlights the major insights garnered from that two-day meeting. It is not a proceedings of the workshop, nor does it represent the consensus of the participating members.

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1
Introduction

The United States and Japan are now approaching a relationship of comparative strength in fields of science as well as technology. Japan's success in the marketplace is based on engineering capabilities, in particular those that contribute to the development and commercialization of high technology products. While the strength of American scientific research is unmatched anywhere in the world, new efforts will be needed to maintain leadership in many fields of science, to improve capabilities needed to acquire and adapt technology from abroad, and to efficiently produce and market products globally.

This new context presents challenges and opportunities for American and Japanese researchers, businesspeople, and policymakers. A central question is how to improve access to Japanese science and technology. Improved access and collaboration in research and development (R&D), if carefully structured, should ultimately benefit both countries. There is a special urgency because of the very real possibility that frictions and restrictions will result if these questions are not addressed effectively and soon enough.

There are many reasons that can be given for why there are so many more Japanese researchers in U.S. laboratories than vice versa. The dearth of American technical personnel with Japanese language capability, the lack of Japanese experience in transferring technology to advanced industrial countries, the weakness in U.S. capabilities to access foreign technology, and inadequate knowledge of where the best research is going on in Japan all come to mind. These factors all relate to differences in the ways that the two countries conduct R&D. They also highlight the need for improved understanding of how Japan's R&D system works. "You have to know the system" to work it and work in it—this is the basic rationale for a series of bilateral meetings organized by the National Research Council's Office of Japan Affairs in cooperation with the Japan Society for the Promotion of Science (JSPS) and other organizations in Japan.

The value of a U.S.-Japan dialog on R&D systems is clear for Japan as well. For years, Japanese researchers have experienced first hand the working environment for research in the United States. Today, however, Japan is attempting to improve its basic research effort as well as to move into new fields of advanced technology R&D. In this context, there is still much that Japanese researchers can learn from the U.S. R&D system.

This report covers insights gained from a two-day bilateral meeting held on June 5 and 6, 1989 at the Beckman Center, the West Coast meeting center of the National Academies of Sciences and Engineering in Irvine, California. The participants included senior scientists, engineers, and research managers from national laboratories, private corporations, and other organizations in the two countries. The meeting was designed to focus on organizations that are neither purely academic nor purely industrial—the wide array of national laboratories, professional associations, consulting organizations, and "hybrid" organizations (such as government-sponsored joint R&D projects carried out by industry in Japan). The two chairmen were Roland Schmitt, president of Rensselaer Polytechnic Institute and formerly senior vice president, science and technology at General Electric, and Sogo Okamura, professor of Tokyo Denki University and former dean of the school of engineering of the University of Tokyo. The meeting was the second in a series of three. A report of the first meeting, *Learning the R&D System: University Research in Japan and the United States* is available from the Office of Japan Affairs. A third meeting on industrial R&D is planned for early 1990.

Prepared by the Office of Japan Affairs, this report highlights parts of the discussion that shed light on the way that R&D is conducted in the two countries, and on the broader implications for collaboration between the United States and Japan. It is not a consensus document or a conference proceedings. Nor is it an exhaustive treatment of the many non-academic, non-industrial research organizations in the United States and Japan.

2

Comparing the Non-Academic, Non-Industrial Research Organizations In the United States and Japan: Overview and Categorization

In both the United States and Japan there are a host of organizations not easily categorized as "academic" or "industrial" that perform important roles in R&D (see Table 2-1). Categorizing these organizations in either national context is not an easy task, since they take many forms and perform a wide array of functions. Comparing and contrasting the organizations in the two countries is even more challenging, because organizations called by similar names may perform quite different functions and are in many cases funded and organized in strikingly different ways.

There are a number of reasons why comparing and contrasting these organizations is nevertheless worthwhile. According to the National Science Foundation (NSF), in 1985 government and not for profit organizations together performed significant shares of the total R&D effort in both countries—13 percent in Japan and 15 percent in the United States.[1] There are more than 1,000 "research institutes" in Japan that spend as much as Japan's colleges and universities on R&D.[2] In Japan, this category of research institutes includes government laboratories and other organizations that are not expected to be self-supporting, as well as special corporations that are. Nippon Telegraph and Telephone (NTT), which from a U.S. perspective might be called a joint stock company by virtue of the fact that stock ownership is shared by the government and the private sector, falls into this category although it is called a private company in Japan.[3] Expenditure per researcher in these organizations, moreover, was three times that in universities and even exceeded the per researcher expenditure in Japanese companies in recent years.[4]

Another reason for making the effort to learn more about these organizations

TABLE 2-1 Non-Academic, Non-Industrial Research and Development (R&D) Organizations in the United States and Japan

Ownership, Funding

	Government	
	Government-Owned Government-Operated National Laboratories Government-Owned Contractor-Operated National Laboratories *Special Corporations (staffed by civil servants or private employees—Japan only)	
Functions	*United States*	*Japan*
Basic Research	Fermi High Energy Laboratory Naval Research Laboratory (Stanford Linear Accelerator Center)	National Institute for Radiological Sciences (National Laboratory for High Energy Physics)
Applied Research	Sandia National Laboratories Lawrence Livermore Laboratory Environmental Research Laboratories	Technical Research and Development Institute National Aerospace Laboratory *Japan Atomic Energy Research Institute *National Space Development Agency of Japan *Power Reactor and Nuclear Fuel Development Corporation
Regulations, Standards	National Institute of Standards and Technology	National Research Laboratory of Metrology
Support for R&D Useful to Industry	National Institute of Standards and Technology	Agency of Industrial Science and Technology Research Development Corporation of Japan
Services	Argonne National Laboratory	*Japan Atomic Energy Research Institute *Power Reactor and Nuclear Fuel Development Corporation
Policy Analysis		National Institute for Science and Technology Policy

Note: Representative examples are included. Some organizations perform many different functions. Those in parentheses were covered in previous meeting.

TABLE 2-1 Continued

Ownership, Funding

Private, Non-Profit		***"Hybrids"*** Government-Sponsored Consortia Joint Stock Companies Public Stock Companies	
United States	*Japan*	*United States*	*Japan*
			NHK KDD NTT
Battelle Southwest Research Institute	Professional Associations	Sematech	Key Technology Center Projects Very Large Scale Integrated Circuit project Optoelectronics Joint Research Laboratory Government-sponsored Consortia
Professional Associations	Professional Associations		
National Academy of Sciences National Academy of Engineering National Research Council	Think Tanks		

is that some of them play significant roles in R&D useful to industry. In contrast to the situation in the United States where debates continue over whether it is appropriate and feasible to add a technology transfer mission to the roles of the national laboratories, a number of Japanese national laboratories were established specifically to carry out R&D useful to industry. In 1987, almost 85 percent of the R&D carried out by non-academic, non-industrial research institutions in Japan was reported to be applied or developmental.[5] In the context of increasing interest in the United States in establishing R&D consortia and other organizations that involve government as well as private sector participation in research useful to industry, an examination of some of the "hybrid" organizations established in Japan is timely. However there should be no assumption made that it would necessarily be possible or appropriate to imitate these forms in the U.S. setting.

By virtue of the fact that these organizations are in most cases supported by the government in one way or another, they also offer special possibilities for expanded foreign participation under the terms of the U.S.-Japan Agreement for Cooperation in Science and Technology signed in 1988. Questions about the quality and working environment for research in these organizations, however, cannot be fully resolved here.

This report covers national laboratories, professional associations, consulting organizations, and examples of "hybrid" organizations that involve both government and private sector participation. Based on the discussions of a two-day meeting, the report is in no sense an exhaustive account of the myriad organizations in the two countries that are neither purely academic nor purely private. Senior scientists, engineers, and research managers who attended the meeting emphasized the value of developing a classification that highlights the striking variety of functions and organizational forms apparent in both countries.

The "government-owned" research organizations[6] are perhaps the most familiar of the research organizations under consideration here. In most Organization for Economic Cooperation and Development (OECD) countries, the research effort in the government sector is generally on a par with the higher education sector, but relatively little is known about it and there has been questioning of its role during the past ten years.[7] As will be explored in more detail below, the questioning concerns the contribution that these organizations can and should make to innovation and technology development. In this sense, the U.S.-Japan contrast drawn here should be understood in light of broader trends apparent in the OECD countries.

In both countries, the national laboratories perform a wide range of R&D to meet national goals. Individual laboratories also carry out R&D in a variety of areas. Many U.S. federal laboratories set out to perform basic research; in some cases the research results in useful industrial applications. Although Japanese national laboratories are more oriented toward applications, the National Institute for Radiological Sciences is an example of one that conducts basic physics and chemistry research.[8]

National labs also conduct applied R&D in areas considered to be the responsibility of the government such as energy, the environment, and defense. Examples in the United States include the Department of Energy's (DOE) civilian energy labs, Environmental Protection Agency labs, and defense-related research organizations such as Lawrence Livermore and Sandia National Laboratories. In Japan, the Technical Research and Development Institute (TRDI) is the only government-owned research organization with an explicitly defense-related mission. In contrast to other ministries that operate national labs in Japan, the Japan Defense Agency (JDA), which operates TRDI, has enjoyed significant funding increases during the past five years.[9] Laboratories such as those at the Arnold Test Center in the United States and the National Aerospace Laboratory in Japan carry out applied R&D in the national interest that in some instances is also of interest to industry.

In the United States the National Institute of Standards and Technology (NIST) has played a role in standards development through its industrial research and participation in standards committees. Similar functions are carried out in Japan by Agency for Industrial Science and Technology (AIST) labs, such as the National Research Laboratory of Metrology, under the Ministry of International Trade and Industry (MITI).

A significant contrast can be found in the fact that the AIST labs were established to carry out R&D useful to industry. These labs and the AIST headquarters together had a budget of less than one billion dollars in 1988 and employed 2,500 researchers.[10] While these labs make up a comparatively small percentage of the total budget or staff of Japanese national labs, they represent a distinct contrast to the situation in the United States where there is only one national laboratory (NIST) with an explicit mission of assisting in research useful to industry. For purposes of comparison, NIST operates with an estimated budget of $278 million in 1990 and has 2,900 permanent positions.

It is interesting to note that Japanese national laboratories include the National Institute for Science and Technology Policy (NISTEP), an institute established separately under the Science and Technology Agency (STA). NISTEP does not conduct physical research, but is tasked with science policy development. Although similar types of science policy studies are conducted within the NSF, there is no parallel to NISTEP among the U.S. federal laboratories.

A noteworthy aspect of Japan's research organizations involved in applied R&D is the prominence of public corporations, or *tokushu hojin*, which are legal entities according to government legislation and are largely financed by the government. As noted above, many of these public corporations are not expected to be self supporting, as is the case with the National Space Development Agency, the Power Reactor and Nuclear Fuel Development Corporation, and the Japan Atomic Energy Research Institute. NTT (which is formally privatized but where significant government stock ownership continues) is a self-supporting organization with a market value of more than $160 billion that has no parallel in the

United States. With an operating budget of $43 billion dollars, NTT carries out and commissions a great deal of R&D useful to industry and is included among the special corporations for the purposes of the annual survey of R&D in Japan. It should be noted that public corporations in Japan make up a larger share of R&D expenditure than national laboratories and their budgets have increased significantly in recent years.

When we consider the R&D organizations that are not predominantly government-owned or government-funded and not "purely" private, the private, non-profit professional associations play important but different roles in the two countries. Non-profit professional associations (such as the National Academy of Engineering, NAE) in the United States help to set national priorities for R&D useful to industry and serve as channels for exchanging views among industry, government, and university sectors. The Japan Engineering Academy, recently established, represents a private sector initiative to develop an organization outside the government that performs some of these functions. In Japan, most professional associations are authorized by government agencies. The JSPS, which supports international scientific and technical exchanges, is a semigovernmental organization which has no members but a number of industry-university cooperative committees and other programs. Professional associations and societies in Japan, unlike those in the United States, organize research committees that actively carry out projects in applied areas such as the development of computer-aided design and manufacturing (CAD/CAM) systems.

There are no counterparts in Japan to the private, not for profit consulting organizations, such as Battelle and Southwest Research Institute, that perform R&D for government as well as industry. Consulting organizations per se are a comparatively new phenomenon in Japan and the best known are private organizations that apparently still perform some work for their parent organizations. Mitsubishi Research Institute (MRI), for example, has no laboratories and does not carry out physical R&D in the sense that Battelle does.

In Japan, however, there are many engineering research associations that are organized as non-profit legal entities to carry out specific research projects and are administered by government agencies. Engineering research associations administered by MITI are particularly prominent.[11] By virtue of the fact that funding is shared by the government and private industry, these organizations can best be viewed as "hybrids." Organized to carry out specific projects, they are dissolved or modified once the task has been completed.

A distinctive feature of Japan's R&D system is the proliferation of research associations and other "hybrids" that enjoy some government funding but encourage considerable initiative on the part of private companies involved. The Japan Key Technology Center, with 70 percent of its funding from government, is a good example of how MITI can act as a venture capitalist to encourage R&D carried out by companies in their own laboratories. Other examples, discussed more fully below, include government-sponsored consortia of private sector companies involved in generic research useful to industry in fields like optoelectronics. Adaptation and organizational experimentation with hybrid forms is under way in both countries, but Japan has by far the larger number of such "hybrid" R&D organizations and the longer track record. In the United States, Sematech represents an effort to build indigenous U.S. capabilities in semiconductor technology research and manufacturing. It is, however, a comparatively new experiment. In contrast, Japan's engineering research association system was established in 1961, inspired by a British system of cooperative research.[12]

This complex mosaic of organizations that are neither purely academic nor purely private corporations play important and highly varied roles in the R&D systems of Japan and the United States. In both countries significant change is under way as many of these organizations are challenged to adapt to rising R&D costs and requirements for new expertise. In the sections that follow, these trends will be outlined in more detail and organizational differences will be explored with reference to specific organizations that are chosen for their importance in the respective system rather than because they are "representative" of all such organizations.

3

National Laboratories, Special Corporations, and Other Government-Owned Organizations

In the United States, there are 400-700 federal labs,[13] ranging from the government-owned contractor-operated (GoCo) labs of the DOE to the government-owned government-operated (GoGo) labs under other departments.[14] They include large multipurpose labs (eg., Oak Ridge National Laboratory), single-purpose labs (eg., Fermi High Energy Laboratory), and user facilities (eg., the synchrotron light source at Brookhaven National Laboratory). There are 94 national labs under 17 different ministries in Japan. Although Japan has no counterpart to the large multi-program labs of the DOE, its labs are nonetheless varied, ranging from industrial engineering-oriented labs to those with a policy orientation.[15]

The U.S. government performs about 12 percent of the nation's R&D, compared to the Japanese government, which performs 9 percent of that nation's total R&D.[16] Japan's national laboratories, however, operate on only 3.3 percent of total national R&D expenditures, a share that has been declining with increasing R&D expenditures by Japanese industry. Japan's 1988 national lab budget was 256,544 million yen ($2 billion), compared to U.S. federal lab expenditures for R&D of an estimated $15.5 billion in 1987. If national laboratories are strictly defined, Japanese national labs receive a relatively small share of the *government's* R&D budget as well—14.1 percent—compared to U.S. federal labs, which receive 25.6 percent.[17] While the share of the government R&D budget allocated to national labs has remained fairly constant in both countries since 1980, the overall U.S. government R&D budget has grown more quickly than the Japanese government R&D budget.[18]

These data do not, however, include Japan's eleven public research corporations, eight of which conduct their own R&D with significant government funding. An additional 21.5 percent of the Japanese government R&D budget goes to these institutions. According to the STA, six of these research organizations received 293,172 million yen ($2 billion) in government capital funds, and an additional 63,512 million yen ($439 million) in subsidies in 1987.[19] On the U.S. side, the data do not reflect expenditures made in federally funded research and development centers (FFRDCs), which are administered by universities, industry, and non-profit institutions. In 1987, the U.S. federal government spent an estimated $3.8 billion for R&D in the FFRDCs administered by universities and colleges alone.

HISTORICAL EVOLUTION

Whereas the overall role of Japanese national labs has been to reinforce the nation's industrial base, increase the Japanese standard of living, and promote science and technology generally, the role of U.S. labs has included a major focus on R&D needed for national security, energy, the environment, and health, and the construction of large user facilities. Japanese national labs have continued to be more oriented toward research that is useful to industry than have their U.S. counterparts. A review of the historical evolution of U.S. and Japanese national labs helps to explain these differences.

Government performance of R&D has a long tradition in both the United States and Japan, particularly in areas like agriculture and the standardization of measurements. One of MITI's most prestigious labs, the Electrotechnical Laboratory (ETL), for example, began testing porcelain insulators for telegraph cables during the 1870s. Formally established in 1891, ETL has been compared to the U.S. Department of Commerce's NIST, which was founded in 1901 as the National Bureau of Standards to establish basic measurement standards for industry.

In both countries many new government labs were created after World War II. After 1945, the U.S. government reverted to its prewar position that it should not be responsible for private sector R&D, while the Japanese government focused on helping industry as part of its efforts to mend its war-torn economy and "catch up" with Western technology. Between 1945 and the mid-1960s, DOE labs transferred nuclear technology to industry, in part through educational efforts, and moved into basic, non-industrial research areas such as nuclear medicine.[20] During the same period, ETL took on a leading role in adapting and developing transistor, integrated circuit, and information processing technologies for industrial use.

During the 1960s the Japanese government made its first serious attempt to establish a comprehensive policy concerning its national labs. Japan's Council on Science and Technology made recommendations in 1960 and 1963 that identified fields considered appropriate for national lab R&D, laid the foundations for

Japan's public research corporations, and initiated construction of a science city in Tsukuba, now the world's largest. Although the Council included recommendations that the labs focus on R&D that would contribute to the improvement of public welfare and long-term R&D that could not be performed by private industry, in retrospect it is clear that in this era of "catching up," the public welfare was defined in terms of industrial and economic strength. In other words, R&D that industry was interested in but that industry itself could not perform was seen as appropriate for national laboratories. One of ETL's *raisons d'etre* during this period was to adapt Western technology for Japanese industrial use.[21]

With the rise of environmental concerns and the onset of the first energy crisis, the missions of U.S. federal labs, particularly the DOE labs, were expanded in the late 1960s and 1970s. DOE laboratory missions were expanded to include R&D on all energy technologies and on the generation, conservation, and effects of alternative sources of energy. Japan's AIST labs also began focusing more on alternative energy sources and energy conservation R&D during the 1970s, although this was not part of a comprehensive policy to change the role of Japanese national labs.

THE CHANGING ROLES OF NATIONAL LABS

Although the 1980s have brought a reevaluation of the roles of national labs in both countries, significant, concrete shifts in direction have not yet manifested themselves in either the United States or Japan. Despite recent Japanese policy emphasis on more creative, basic research, many national lab efforts in Japan continue to focus on applied areas expected to be useful to industry. Similarly, despite increased attention in the United States to technology transfer from federal labs to industry, it appears unlikely that technology transfer will become the primary mission of many U.S. federal labs.

Recognizing that Japan had "caught up" with the West in industrial technology, the Council on Science and Technology in 1984 and 1987 encouraged more "creative" research and international cooperation. Japanese policymakers view science and technology as critical to an emerging new role for Japan in the twenty-first century. Because creative research is seen to be hampered by the lack of mobility of technical personnel in Japan, the Japanese government passed the Research Exchange Promotion Law in 1986 to facilitate cooperation between national labs and other sectors through personnel exchange and the use of common facilities. This law also allows national labs to hire foreign researchers as employees. The Research Development Corporation of Japan (JRDC) is establishing a new program to promote and administer international research exchange in fundamental fields. The JRDC has also been placed in charge of STA fellowships for foreign researchers.

This reevaluation of the roles of Japanese national labs was stimulated primarily by improvements in the R&D capabilities of Japanese *industry* that have made some national lab programs redundant. In the past, Japanese national labs were able to remain one step ahead of private corporations, first by revising Western technology, and later by developing their own. Examples of technology adapted or developed by ETL and transferred to the private sector include transistorized computer technology in the 1950s, pattern recognition in the 1960s, intelligent robot technology in the 1970s, and Josephson junction and synchrotron radiation technology in the 1980s. A basic dilemma of Japanese national labs is how they can, with stagnant government budgets, continue to be of assistance to an industrial base that has surpassed them technologically in many areas.

In the absence of a consensus on what constitutes "basic research," Japan's current policy emphasis on promoting more basic research raises some questions. On the one hand, in conjunction with a new emphasis on internationalization, Japan's official policy is oriented more toward scientific research that will add to the global pool of knowledge. On the other hand, there is no expectation that national labs should divorce themselves from the needs of industry; nor is there any evidence that they intend to do so. In fact, some national lab representatives see a way to lead private industry by conducting research in fields that are of interest, but unfamiliar, to Japanese companies. Some argue that this amounts to a "reduction theory": national labs should be responsible for R&D *not* conducted in other sectors of the R&D system. As a result, Japanese national labs have begun to see their role in "high-risk, large-scale" R&D. In keeping with historical trends, however, large-scale projects, such as those sponsored by MITI, tend to be in *applied* areas expected to be useful to future industries and depend upon industry participation.

Increased concern about global competitiveness and its importance to national security have also made the roles of U.S. national labs increasingly difficult to define. Although many have been charged with more long-term, high-risk research since the onset of the 1980s, their role in transferring technology to industry, long taken for granted in Japan, has recently received considerable attention in the United States. This new mission is not, however, universally accepted as a wise one.

In order to accomplish more technology transfer from federal labs, a number of steps have been taken. These include the creation of offices of technology transfer in the federal labs, changes in patenting and royalty mechanisms that permit companies to acquire exclusive licenses and federal lab researchers to receive a percentage of the royalties from commercialized technology, and reimbursement schemes that allow private companies to conduct proprietary research at federal user facilities like the synchrotron light source at Brookhaven National Laboratory. Many of these changes have been embodied in legislation.[22]

The responsibilities of U.S. federal labs have also grown to include the construction and operation of major user facilities, including particle and photon accelerators, environmental research parks, and materials labs. These facilities are open to industry researchers and have become popular with foreign researchers as well. Last year, 600 of Oak Ridge's 2,300 guest researchers came from industry, up dramatically from just a few years ago.[23]

Disagreement continues, however, on the extent to which links between federal labs and industry have been built and on whether they should be attempted. To many, U.S. government labs make research contributions in their own right, and solutions to the specific needs of industry cannot be found by making technology diffusion a major role of the federal labs. Although there is evidence of an increase in the number of patents issued by some federal labs to industry, skeptics wonder if more patents might not have resulted had the same research been conducted within industry.[24]

It may just be too early to judge the success or failure of efforts to increase technology transfer from U.S. federal labs. Technology transfer takes time; some estimate that it takes thirty years for research results to be fully integrated into product technology and to demonstrate all the potential impacts on the economy. Changes in U.S. judicial attitudes toward antitrust to allow experimentation with cooperative industrial R&D have occurred only recently. There is a long tradition of tension between U.S. government and industry to be overcome before new mechanisms can be created that encourage the two to join forces.

In fact U.S. federal labs have already made major contributions to some sectors of U.S. industry. DOE labs, for example, have played a crucial role in interactions with industry in light source research, small angle neutron scattering, polymer research, high temperature aqueous chemistry, and ceramics. Many believe that defense procurement and research contributed to the development of the U.S. computer industry.

In some ways, NIST has been a model for government-industrial collaboration. NIST has a high proportion of guest researchers to staff, published 1,600 papers last year, and holds countless meetings every year that are attended by researchers from universities, industry, other federal labs, and foreign countries. NIST has long been a "meeting ground" for researchers from all sectors. NIST, and its technology transfer activities in particular, have not, however, been well-funded. The controversial nature, even within NIST, of many newly mandated functions related to technology transfer leaves the outcome of these programs in doubt.

Thus, although there is some support for the notion that U.S. federal labs can make modest contributions to global industrial competitiveness, few believe that technology transfer is likely to become *the* major role of the labs. The materials and instrumentation industries are considered likely candidates to benefit from DOE lab contributions, but many U.S. federal labs focus on basic research and some companies have complained that preference for access to expensive user facilities is provided to firms conducting "exotic" research (as opposed to routine qualification work). Corporate researchers do not see federal labs as a major source of technological information useful to industry.

ORGANIZATION AND MANAGEMENT OF RESEARCH

In both the United States and Japan, the official research program planning process begins with proposals from the lab's researchers, which are reviewed by the lab's management and then presented to the department or ministry in charge. The planning process in both countries involves considerable discussion between the lab and the administrative agency. DOE labs make plans with five and fifteen year horizons. Major changes in the research agenda of both U.S. and Japanese national labs are, however, difficult to accomplish from within.

The large, multipurpose DOE labs are organized in a matrix-type management system. Program directors with no permanent research staff of their own are responsible for allocating funds and managing particular projects. These program directors gather their staff for individual projects from a central disciplinary division, which manages the lab's technical research staff. The fact that the disciplinary division is responsible for the quality control of the research staff helps to ensure uniform, high quality research.

In a similar type of organization, the Japanese National Institute for Research in Inorganic Materials (NIRIM) assembles research teams for particular projects, which usually last about five years. NIRIM is, however, different from most Japanese national labs, in that it is organized around materials that are the subject of research, rather than by scientific discipline. NIRIM's directors also include industry representatives. Most Japanese national labs draw their directors and research division directors from within the national lab or from the lab's parent ministry.

In theory, Japanese national lab responsibilities are divided by research field. The number of labs involved in materials research, however, belies the ostensible division of labor (see Table 3-1). In the United States, too, there are many federal labs working in similar fields of research. Basic energy research, for example, is conducted by labs supported by DOE, NSF, and the Department of Defense.

INDUSTRY-NATIONAL LAB RELATIONS IN JAPAN

As noted above, the role of national labs in transferring technology to industry continues to be somewhat controversial in the United States but has long been accepted in Japan. There are a variety of ways in which industry is involved with the work of Japanese national labs.

Although most Japanese national labs are not like NIRIM, where industry has a direct say in oversight of the research agenda, Japanese ministries all have advisory committees consisting of representatives from industry and academe. Through these advisory committees, representatives from other sectors can exchange information and contribute to national lab agenda setting. Japanese corporations also send researchers to national labs and support contract research

TABLE 3-1 Sampling of the Variety of Japanese National Laboratories involved in Materials Research

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Ministry of International Trade and Industry, Agency for Industrial Science and Technology:

- Mechanical Engineering Laboratory
- National Chemical Laboratory for Industry
- Research Institute for Polymers and Textiles
- Electrotechnical Laboratory
- Government Industrial Development Laboratory, Hokkaido
- Government Industrial Research Institute, Tohoku
- Government Industrial Research Institute, Nagoya
- Government Industrial Research Institute, Osaka
- Government Industrial Research Institute, Kyushu
- Government Industrial Research Institute, Shikoku
- Industrial Products Research Institute

Science and Technology Agency:

- National Research Institute for Metals
- National Institute for Research in Inorganic Materials

by paying for the work of national lab researchers. The National Research Institute for Metals (NRIM), for example, conducts creep and fatigue tests for industry. The number of joint programs between industry and national labs has also been on the rise in recent years. Whereas there were only six such programs between industry and the national labs of the STA, MITI, the Ministry of Construction, and the Ministry of Agriculture, Forestry, and Fisheries in fiscal year 1985, that number had increased to 32 by fiscal year 1988. The government budget for these programs has correspondingly increased from 157 million yen to 547 million yen.[25]

Japanese industry also makes considerable use of Japanese national lab equipment and facilities. One quarter of the companies surveyed by the STA in 1988 and 40 percent of those worth over 10 billion yen made use of national lab facilities.[26] ETL also has a "tutoring" program, through which it has transferred many newly developed technologies to industry. ETL offers over 200 tutoring programs every year; all five of the aforementioned technological advances made by ETL have been transferred to industry via its tutoring program.

Despite recent efforts to encourage greater researcher exchange from national labs to the private sector, the flow continues to be one-sided in Japan. A recent survey indicated that for nearly 500 industry researchers dispatched to national labs in 1988, there was only one national lab researcher who spent time in an industry laboratory.[27]

There are a number of specialized organizations that have been created in

Japan specifically to serve a technology transfer function from government labs to industry. These include the Japan Industrial Technology Association (JITA), established by MITI. JITA participates in MITI's R&D planning process, publicizes national lab research accomplishments, and conducts technological exchange activities and technology assessments.

The JRDC, mentioned above, is particularly active in technology transfer. Established in 1961 by the STA, the JRDC functions primarily to exploit government-owned patents by selecting and supporting companies that develop technology based on national university and government lab research results that might not otherwise be exploited in the commercial marketplace. If the company is successful, JRDC support is considered a loan to be repaid and the company is permitted to license the patent from JRDC; if the company is not successful, it is under no obligation to repay.[28]

The JRDC funds and administers the Exploratory Research for Advanced Technology (ERATO) program, created in 1981 to join the research efforts of the private and public sectors in creative, multidisciplinary research in advanced technologies. The ERATO program, which is open to foreign researchers, consists of a number of five-year projects, for which researchers from public and private institutions are hired on one or two-year contracts. As it has no research facilities of its own, ERATO research is conducted at the home institutions of the researchers involved or in rented laboratories all over Japan. The JRDC coordinates the projects and moves the research results into technology development by licensing resulting patents.[29]

Despite a lack of consensus on the most appropriate relationship between federal labs and industry in the United States, there are a number of mechanisms through which U.S. industry and federal labs can cooperate. These include sponsored research, employee exchange, industrial use of special facilities such as that at Brookhaven National Laboratory, recently instituted regulations that allow exclusive licenses to be issued from federal labs to private companies, and the activities of the Federal Laboratory Consortium, established in part to help industry identify appropriate research under way in federal labs.

NTT—A SPECIAL CASE

One *former* public corporation, NTT, deserves special mention. With 1988 sales of nearly $40 billion, NTT ranks among the world's largest corporations.[30] The company's operating revenues are about $43 billion and, with 270,000 employees,[31] it is Japan's largest employer.[32] A public corporation for over thirty years before it became legally privatized pursuant to the Nippon Telegraph and Telephone Corporation Law in 1985,[33] NTT, with 50 million subscribers, continues to dominate Japan's telecommunications market.

NTT devotes $1.6 billion (3.8 percent of its yearly operating revenues) to R&D, employing 6,000 people in its eleven laboratories and two development centers. NTT has always focused on applied, industry-oriented R&D. The fact that Japanese industry has long been willing to send its best researchers to work on collaborative projects with NTT is testimony to the high quality of NTT's applied research. NTT's R&D efforts include telecommunications network development and services (ISDN, intelligent networks, personal communications), components technology (LSI, photonics, software engineering, satellite communications), and related technological areas such as artificial intelligence and new materials.

With no manufacturing capability of its own, one of NTT's chief roles has been to disseminate the results of its research widely to industry; technology is transferred through licensing. The company is composed of R&D and business sectors. NTT maintains close relationships with industry through its business sectors, and can translate the needs of industry into efficient R&D targets via close ties between NTT's internal business and R&D sectors. The movement of technology from basic to applied research and to developmental stages is accomplished in part by the fluidity of personnel within NTT: Some of the researchers involved in the early stages of a research project are later assigned to the development of the technology, shortening development time and increasing productivity.

FUNDING AND EMPLOYMENT

Together, the eight DOE multipurpose labs spend about $4.5 billion a year, with the average DOE lab budget about $400 million. While the DOE labs are some of the largest in the United States and there are no multipurpose labs in Japan with which to accurately compare them, some Japanese national labs also have large budgets. JDA's 1988 national lab budget, for example, was 81,756 million yen (about $638 million);[34] the next largest agency in terms of national lab budget was the Ministry of Agriculture, Forestry and Fisheries, which received 56,502 million yen ($441 million).

The sixteen MITI labs specifically created to conduct research useful to industry together had a budget of 113 billion yen ($885 million) in 1988.[35] The largest of these, ETL, had a budget in 1987 of 9,447 million yen ($65 million), smaller than NIST's total budget of $225 million for the same year.[36] In terms of both share of GNP and of government R&D budgets, however, NIST is smaller than similar labs in Japan.[37]

NIST's technology transfer activities have also received scant funding. Only a small percentage of its R&D budget is allocated for the dissemination of results. Similarly, although NIST has recently been tasked with establishing Manufacturing Technical Centers (MTCs) for technology transfer, extension services similar to those of the Department of Agriculture, a coordinating function for state services, and an advanced technology program to support government-industrial-academic consortia, only three MTCs were funded in 1989

Both countries' national labs have multiple funding mechanisms to allow flexibility in choosing research projects. Japan distinguishes between "ordinary" and "special project" research. Funds allocated for "ordinary" ongoing research efforts represent steady annual funding for the lab and amount to about 1.4 million yen per researcher per year. These funds can be spent with more flexibility than those allocated for special research projects, which are larger projects selected by the lab. Special research project funding is obtained by a separate request to the Ministry of Finance.

In the United States, DOE labs have a seed money system that allows individual researchers to propose projects. Formally, DOE lab directors are empowered to set aside 2 percent of the lab's research funds under this system. Creative researchers can also receive funding by developing a cooperative program with industry or another federal lab. The Advanced Energy Project program of basic energy sciences at DOE is one mechanism by which creative, unusual proposals that might not be funded through regular channels can be pursued. In addition, U.S. federal agencies are required to allocate 1.25 percent of their R&D budgets to Small Business Innovative Research grants.

U.S. federal labs are much larger than their Japanese counterparts in terms of employment. Most civilian DOE labs, for example, employ 2,000-5,000 people; DOE weapons labs can be twice as large. In comparison, all of Japan's national labs employ less than 16,000 people. ETL, one of Japan's largest national labs, employs only 560 research staff. Japanese national labs are also troubled by government budget stagnation, which has resulted in a leveling off in the number of new hires.[38]

In the United States, visiting and guest researchers account for a significant portion of the work conducted at federal labs. The 2,300 guest researchers at Oak Ridge National Laboratory, which has a total scientific and engineering staff of 1,600-1,800, for example, represented the equivalent of 600 full time employees. The contribution of guest researchers to a lab like NIST is especially significant. Although not expressed in terms of full-time equivalence, the numbers are nonetheless striking. With nearly 3,000 employees, about half of whom are professional and technical staff, NIST hosted 1,090 guest researchers in residence during 1988.

Information on visiting researchers in Japanese national laboratories is incomplete, but available data indicate that they do not play as significant a role in Japan as they do in some U.S. federal labs. In fiscal year 1987, for example, the AIST labs invited a total of 382 guest researchers—145 from abroad and 237 from within Japan (most from universities). This can be compared to a total researcher force in 1988 of 2,577.[39] Other national labs on which data are available invited far fewer guest researchers.

4

Consulting Organizations

Consulting organizations have grown in both the United States and Japan in recent years. These organizations are private entities that perform R&D for or provide technical advice to clients and are reimbursed for their services. They may or may not operate for profit. Their clients include universities, private firms, and government agencies. Although this broad definition covers many U.S. and Japanese organizations, the differences between U.S. and Japanese consulting organizations—in terms of historical evolution, roles, organization, and resources—are more striking than the similarities.

The most difficult aspect of such a comparison arises because an important type of U.S. consulting organization—private, not for profit research institutions with their own physical research laboratories—does not exist in Japan. There are no Japanese equivalents to institutions like Southwest Research Institute or Battelle, the major focus of discussion here. The closest Japanese approximations, Mitsubishi Research Institute (MRI) and Nomura Research Institute, are really quite different.

HISTORICAL EVOLUTION

Private, not for profit research institutions have a comparatively long history in the United States. Battelle Memorial Institute was established in 1925 and became involved in significant R&D activities in xerography during the mid-1940s. During the period shortly after World War II, seven other private, not for profit organizations—Stanford Research Institute (now SRI International), Illinois Institute of Technology, Midwest Research Institute, Southern Research

Institute, Triangle Research Institute, Southwest Research Institute, and Franklin Institute—also became major players in U.S. R&D. Of these eight U.S. consulting organizations, seven are still in operation today.[40]

The "small band of pioneers" who founded the eight U.S. private, not for profit consulting institutions did so in response to the U.S. government's decision after World War II to revert to its prewar policies of not supporting private sector R&D. The organizations established were not meant to benefit any particular industry, but to support industry in general. Although some were originally based in particular regions of the United States (Midwest, Southern, Triangle, and Southwest Research Institutes), their founders saw their role in the overall postwar industrialization process.[41]

In contrast to the long history of private, not for profit U.S. consulting organizations, Japanese "think tanks" were created in the 1970s. Also in contrast to the not for profit U.S. consulting organizations, Japanese think tanks were established largely to help the government respond to problems created by industrialization—pollution, urbanization, and transportation problems. With strong connections to national or local governments, the Japanese think tanks were established to work on national issues being ignored by private industry, as well as to provide specialized support. Government-commissioned projects account for a large proportion of Japanese think tank activity. The fact that the Japanese government played a more significant role in the nation's industrialization may explain why private consulting organizations with their own facilities for conducting industrial R&D did not sprout in Japan as they did in the United States.

ROLES

The seven major private, not for profit U.S. consulting organizations all have physical research facilities and conduct a great deal of applied and experimental research. Their applied engineering work spans areas as diverse as the auto industry, nuclear and fossil fuel plants, nondestructive testing, space science, medical electronics, software, chemical engineering, materials engineering, and optoelectronics. Their products include technical analysis, technology innovation, and technology transfer, all of which depend on internal technical expertise. Southwest Research Institute's work for the auto industry, for example, involves developing technology to meet new environmental pollution standards.

Japanese think tanks like Nomura Research Institute and MRI, on the other hand, perform no physical research and have no laboratory facilities, although they do have computer systems. These organizations conduct research in areas such as macroeconomic analysis, techno-economic studies, corporate behavior and management, environment and energy, urban and regional issues, social systems planning, information technology, engineering analysis, and computer software development. Some of these organizations are also involved in information and data processing services, but none directly conduct physical scientific research. Typical examples of the products of Japanese think tanks are MRI's design of a national transport system for the twenty-first century and identification (not development) of technologies needed to implement the concept of underground living space in crowded Japan.

An important aspect of the role of private, not for profit U.S. consulting organizations as contract researchers for industry is their ability to maintain confidentiality and independence. The fact that the seven major private, not for profit U.S. consulting organizations have been in business for so many years without violating the confidentiality of proprietary information is testimony to the effectiveness of their systems. Great care is taken to see that conflicts of interest are avoided between ongoing projects.[42]

Japan's major think tanks are all affiliated with a large business group. MRI, for example, is a part of the Mitsubishi group. Some believe that Japanese companies outside the Mitsubishi group may be reluctant to turn to MRI to conduct sensitive, proprietary research because of a potential conflict of interest. Although it has been argued that large Japanese companies, which have their own considerable R&D capability, have no need to contract research outside, the fact that some large Japanese firms are contracting research from U.S. consulting institutions indicates the existence of a Japanese market for high-quality, independent research that is not being adequately served domestically.

There are Japanese consultants who work with proprietary information from many different companies. The principal "consultant" is usually an individual—often a university professor or a researcher in a governmental or semi-governmental laboratory. These individuals work for companies *as individuals* and not as representatives of the organizations by whom they are employed; they may not even be paid directly by the companies. Enjoying the trust of Japanese corporations similar to that enjoyed by private, not for profit consulting organizations in the United States, they are sometimes identified by industry through their participation in professional associations.

Consulting organizations can be called "bridges" for a variety of reasons, but differences between the capabilities of U.S. and Japanese consulting organizations dictate different types of bridging roles. Consulting organizations can be bridges by offering technical advice or conducting R&D of a type not available within their clients' facilities, by acting as intermediaries between their clients and others as a consequence of their specialized knowledge, or by absorbing, "adding value" to, and disseminating information to and from a variety of organizations.

Japanese think tanks are less capable than U.S. consulting organizations of in-house technology development but they are particularly well-suited to disseminating information and in some cases helping to build consensus among organizations within the science and technology community. An example of a U.S. consulting organization's activities in the collection and dissemination of information is Battelle's multiclient program on "Advances and Opportunities in

Nonlinear Optical Materials," which permits subscriber companies access to research literature analyses and forecasts.

Photonic Integration Research Inc. (PIRI), a joint venture company located on the Battelle campus in Columbus, Ohio, is an example of a bridge between research and developmental applications as well as an international bridge. Through PIRI, Battelle is working in partnership with Mitsubishi Corporation and NTT to commercialize an advanced fiber optic component technology developed by NTT.

Consulting organizations bridge international boundaries, but some in the United States perceive consulting organizations to be primarily a one-way bridge from the United States to Japan. Japanese companies are increasingly contracting research from private U.S. consulting institutions. Battelle, for example, reports rising numbers of programs involving Japanese clients, most of which are coordinated through Battelle's relationship with Mitsubishi. Southwest Research Institute has a similar arrangement with the Mitsui Technical Development Center. Japanese companies also appear more eager to take advantage of the services offered by U.S. consulting organizations than are U.S. companies. The Battelle program on nonlinear optics, for example, has attracted 27 Japanese and three European companies, but only one U.S. subscriber company.[43] Battelle's efforts to commercialize an NTT-developed technology, mentioned above, is an example of technology flow in the other direction—from Japan to the United States.

Reflecting their broader scope, the private, not for profit U.S. consulting organizations are large employers. Battelle, for example, employs 7,500 people and Southwest Research Institute has 2,400 employees. MRI employs only 700.

The backgrounds of these employees are also different. Private, not for profit U.S. consulting organizations employ many scientists and engineers. In contrast, the professional staffs of Japanese think tanks may have expertise in fields like economics and computer science, but they have limited internal staff with technical or engineering expertise. They go outside the company when contracts require technical expertise.

Although the major U.S. private, not for profit consulting organizations under consideration here count the government among their clients,[44] they pride themselves on the fact that they do not receive government subsidies. They may depend on U.S. government contracts for a significant portion of their research activities, but they do not receive any "base" or "guaranteed" government funding.

5

Professional Associations

Professional associations are non-profit entities formed of individuals involved in particular technical disciplines or industrial sectors.[45] These associations are held together by the common bonds of scientific or engineering disciplines and are among the most open communication channels available for the dissemination of international scientific and engineering information, both nationally and internationally. As such, professional associations may represent opportunities for increased access to scientific and technical information in the two countries.

HISTORICAL EVOLUTION

Professional associations have a century-long history in both the United States and Japan. The American Society of Civil Engineers, the American Society of Mechanical Engineers (ASME), and the Japan Society of Mechanical Engineering (JSME) were all established in the nineteenth century.[46] Professional associations have continued to evolve to take into account the development of new fields and interests. In the United States, the Institute of Electrical and Electronic Engineers (IEEE),[47] was formed from a merger of the American Institute of Electrical Engineers and the Institute of Radio Engineers. The Japan Society for the Promotion of Science (JSPS), which is not a membership association, was created as a non-profit private foundation, and later reorganized as a semigovernmental organization.

In the United States, where new professional associations can be created relatively easily by a group of interested parties who establish non-profit status, they are created frequently, multiplying to the extent that there are professional associations within professional associations. They all receive preferential treatment by the government and tax authorities, including reduced postal rates for their publications.

In Japan, however, it is becoming increasingly difficult to receive government authorization to establish new professional associations. Although it is technically possible to create "unauthorized" professional associations in Japan, the advantages to government authorization include the right of members to elect members of the Science Council of Japan and a reduced postal rate for journals. Japanese scientists and engineers with interests in a new field would most likely convene within an established professional association, whereas U.S. scientists and engineers are more likely to form a new association representing their new field of interest.

The U.S. National Academies of Sciences and Engineering, and the Institute of Medicine, because they are different in many ways from other professional associations, require separate mention. The National Academy of Sciences (NAS) was established by government charter as a private, non-profit institution in 1863. The National Academy of Engineering (NAE) was established in 1964 under the same charter, and the Institute of Medicine (IOM) was founded in 1970. Japan has few direct counterparts to these institutions. The Japan Academy's membership includes a broader range of scholars than scientists and engineers. The Japan Engineering Academy was established only recently as a private sector initiative.

ROLES

The professional associations of both countries play similar roles in some areas, but they also perform unique functions. These include the Japanese professional associations' system for cooperative research and the role of some U.S. associations in policy advice to the government. These differences will be addressed further below.

The primary role of most professional associations is information exchange, primarily the exchange of research results. In the United States, professional associations have contributed by forming "invisible colleges" because of their effectiveness in promoting interchange and interpersonal networks among people with similar technical interests. In Japan, established professional associations like the JSME and the Japan Society of Tribologists (JAST) consider information exchange their primary function.

As they add transnational issues to their traditional concerns with national issues, professional associations can also be bridges between the scientific communities of different nations. The NAS has long been involved in international exchange activities; the NAE has played a leading role in the Council of Academies of Engineering and Technological Sciences. The IEEE has a very active section in Tokyo. In Japan, the JSME has cooperative agreements with the mechanical engineering associations of seven other countries, including with the

ASME.[48] Japan's Civil Engineering Society recently became the first Japanese professional association to establish a scientific exchange fund to aid engineering researchers from developing countries who wish to conduct research in Japan.[49] JSPS, the semigovernmental organization noted above, considers the support of international cooperation in science one of its primary roles, and devotes up to 60 percent of its budget to international programs.[50]

One of the primary mechanisms used by the professional associations of both countries for the exchange of information is conferences and meetings. Annual, local, national, and international meetings, as well as seminars, workshops, and educational programs bring professional association members face-to-face, overcoming some of the barriers to inter-sectoral communication.

Professional association meetings are especially important in Japan because of the large number of papers presented. As many as 3,000 15-minute papers may be presented at one conference. Although these papers are presented without review and may therefore be of mixed quality, they give evidence of new directions of research in progress. Abstracts published for meetings of the Japan Society of Applied Physics (JSAP), for example, can be submitted three months before the meeting, in contrast to the nine-month delay between submission and publication for the Society's English language journal.[51] For many journals, the delay is more than a year.

In Japan, where long-term employment separates researchers from different sectors, professional association meetings also play a particularly important role in the exchange of information among universities, government, and industry. Five hundred sixty-six papers were presented at a recent semi-annual meeting of the Japan Society of Precision Engineering (JSPE), which attracted nearly 22 percent of the association's membership. Statistics from the JSPE meeting, as well as JSME membership statistics indicate that in Japanese academic and engineering associations, the information flow is primarily from university members to industry members (see Tables 5-1 and 5-2).

U.S. professional associations place greater emphasis on publications as a mode of communication than do Japanese professional associations. The IEEE, in addition to its well-known journal, *Spectrum*, publishes 50 journals in specialized subfields of electrical engineering, electronics, and computer science. The American Association for the Advancement of Science (AAAS), publishes *Science*, one of the most widely read and important publications on science and technology policy in the country. The activities of the AAAS are an example of the increasing involvement of U.S. professional associations in public affairs that has come with the rising importance, complexity, and globalization of science and technology. The American Chemical Society releases English translations of abstracts of Japanese and other foreign chemistry and chemical engineering literature through its subsidiary, Chemical Abstracts Service.

In the United States, the NAS was organized to provide advice to the government on scientific and technical matters upon request. Elected members of the

TABLE 5-1 Distribution of Participants and Papers Presented at the March 1989 Semi-Annual Meeting of the Japan Society of Precision Engineering by Affiliation (Percent)

Affiliation	Industry	Universities	Other
Participants	70	20	10
Papers presented	25	60	15

SOURCE: Toshio Sata, "Technology Transfer in Japanese Academic Societies and Engineering Associations," U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

TABLE 5-2 Distribution of Members and Contributed Papers at the Japan Society of Mechanical Engineering by Affiliation (Percent)

Affiliation	Industry	Universities	Other
Members (1985)	73	16	11
Papers contributed	12	84	4

SOURCE: Yukio Hori, presentation, U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

Academy complex (the NAS, NAE, and IOM) join with other professional scientists and engineers in volunteering their time and expertise to the work of the National Research Council. Not a professional organization in itself, the National Research Council was organized by the NAS in 1916 and has become the principal operating agency of the NAS and the NAE in providing services to the government, the public, and the scientific and engineering communities. The Research Council is administered jointly by both Academies and the Institute of Medicine.

As mentioned earlier, there is no direct Japanese counterpart to the Academy complex. The Science Council of Japan advises the central government on scientific matters, but it is part of the government and until recently its members were elected by registered individual scholars. It is not considered a professional association as such, although since 1986, its members have been nominated by members of authorized Japanese professional associations. The Science Council also includes members representing the social sciences and humanities.

The most distinctive role of Japanese professional associations is their system of cooperative research. This system provides for direct industry support of and involvement in the associations' research projects. Such relationships are almost unheard of within U.S. professional associations. The ASME's Center for Research and Technology Development, which manages and organizes research with government and industry support is an exception in the United States.

The major mechanisms used by Japanese professional associations in cooperative research with industry are internal research committees organized to pursue a specific research topic. The ratio of committee members from industry to those from academe is approximately 8:2 in associations focused on engineering and 2:8 in associations that are more academically-oriented. The research committees of engineering associations focus on practical developments of technology. During 1978-1982, for example, the manufacturing engineering research committee of the Japan Society of Automobile Engineers developed user-oriented CAD/CAM systems and standardized computerized programmable controllers.[52]

Japanese academic associations are also active in research with practical industrial applications, in part because the continuation of their research efforts may depend on industry funding. Many have had university-industry *cooperative* research committees in place for many years. JSPS has had such a system since 1933, JSME since 1958, and JAST since 1964. The cooperative research committees are separate from the academic association's other research committees. The exact status of the cooperative research committees is slightly different depending on the association, but all receive support from industry.

R&D committees of the JSPS conduct research for up to three years with government support. These committees conduct the initial stages of research, laying the groundwork for industry-university committees (IUCs), which must have industry support to continue their research. Examples of topics that have been studied by IUCs at JSPS (there have been 153 since 1933) include the life cycle of rolling bearings, thin films technology, optical and microwave technology, nanometer structure electronics, and microbeam analysis. As industry has strengthened its own experimental research programs, however, the research role of JSPS has been diminished. JSPS continues to play an important role in the exchange of information useful to industrial researchers.

Another example of how professional associations work with industry is the JSPE research program for the development of CAD/CAM systems created in 1982. Under that program, the association is currently studying the commercialization process and industrial members of JSPE have developed systems for private commercial use. JSPE was able to institute the program with the support of a budget created by raising the industrial membership fee to $16,000.

The JSME forms subcommittees for each research topic under one industry-university cooperative research committee. JSME has formed 94 such subcommittees in the last three decades; each operates for about three years. There are currently 16 such subcommittees in operation. They receive financial support from industry, as well as from the government. Examples of JSME research topics include nonlinear finite element methodology, ultra-high precision manufacturing, noise reduction, high efficiency production, static dynamic characteristics, computer programs for flow analysis, and thermal engineering.

U.S. professional associations emphasize "service to members." One dimension is career development and employment. In the United States, professional associations often feature seminars and journal articles on employment prospects and issues affecting the profession. This is not a formal activity of Japanese professional associations.

6

"Hybrid" Organizations

One of the distinctive features of Japan's R&D system is the growth of "hybrid" organizations that enjoy support from the government but involve considerable initiative and operational direction from private sector companies. While observers may disagree as to whether particular organizations have achieved breakthroughs in technology, these evolving organizational experiments do represent a variety of mechanisms for government-industry cooperation that have no direct parallel in the United States.

MITI-SPONSORED JOINT RESEARCH LABORATORIES

During the 1970s and 1980s Japan established a number of collaborative research projects with some form of government support or sponsorship. All of them bring together researchers from national and corporate laboratories in efforts to develop technology, in most cases with MITI support. These projects are established to last for finite periods of time. In recent years the direct influence of the government has diminished as organizational mechanisms have been developed that allow the private corporations involved to take on larger roles.[53]

The first and best known project that involved a collaborative laboratory was the Very Large Scale Integrated Circuit (VLSI) project, which ran from 1976 until 1980. The goal of the project was to develop fine pattern lithography using electron beams. It is important to recall that at the time of its establishment, there were conflicting views about the idea of establishing a collaborative laboratory. The concept has been attributed to the Industrial Electronics Division of MITI and leaders in ETL.

The government funded 60 percent of the budget on the condition that the companies would repay the government when they turned profits on the technologies developed. Five participating companies formed an engineering research association. Most of the research was conducted in the separate laboratories of the member companies, although a joint laboratory was established. As the first experiment of its type, the VLSI project encountered a number of difficulties, most of which centered around the need to build trust among competing firms. Close observers also believe that the near-term nature of the research target, defined by a perceived need to "catch up" with IBM, made it difficult to attract the highest quality researchers from the participating firms.

A second generation project, the Optoelectronics Joint Research Laboratory (OJL, 1981-1986), had a more narrow but also more futuristic target: developing multi-dimensional super-lattice technologies with atomic scale control and evaluation. The project involved developing optoelectronic integrated circuits (OEICs) based on existing technology, as well as basic research carried on in the OJL to lay the groundwork for more advanced OEICs. With a budget of $50 million, the OJL was organized in six research groups with researchers from the nine participating companies.

A third generation project, the Optoelectronics Technology Research Laboratory (OTL), was established in 1986 and continues today. Unlike the other two projects, this one was established by the Japan Key Technology Center.[54] In many ways this project is a direct extension of the OJL: the same companies that participated in OJL have become stockholders (along with a few additional companies) and the R&D focus is next generation OEIC technology.[55]

An important feature of all three projects is that the work of the joint laboratory is in basic research, while the participating firms independently pursue more applied research, competing directly in device development. Attracting good researchers has been an issue in each case. In the case of the OJL, six research groups were established, but the fact that the researchers worked in common laboratory space encouraged spontaneous collaboration. Interestingly, researchers in both the OJL and OTL were not at the outset specialists. As time passed, the work of research required cross fertilization of research groups. Observers believe that the neutrality of the joint lab and the focus on more basic research made possible frank discussions uncommon among researchers from competing companies. In the OTL, unlike its predecessors, researchers from different member companies are thoroughly integrated into the research groups and researchers themselves have more freedom in selecting subjects.

Even those directly involved in the joint laboratories argue that there is no easy way to evaluate "effectiveness."[56] Joint research has in these projects become more effective and deeper over time, particularly as the focus has shifted to longer-term goals. According to participants, the member companies are interested and supportive of projects precisely because they are risky and futuristic—not the kind of work they are anxious to or can effectively take on independently.

Projects with futuristic goals can, however, be narrowly targeted to build research intensity (a comparatively large group of top quality researchers working on a well defined area). It is also important to note that as participating companies have built mutual trust, government direction has declined. At the very least, these joint projects are interesting experiments in organizational design. Considering the evolution noted above, it appears that learning has occurred—not only in developing technologies, but also in organizational design.

Another example of a joint effort is MITI's Fifth Generation Computer Project. Planning for the project began in 1979 and in 1982 the Institute for New Generation Computer Technology (ICOT) was formally established and a ten-year development plan initiated. The purpose of the project is to develop the technologies needed for a new type of computer. There are more than 100 researchers now working at ICOT from member organizations that include national labs, NTT, KDD (Kokusai Denshin Denwa), and corporations such as Fujitsu. With a $40 million budget in 1988, ICOT researchers are working on basic software development as well as parallel processing and relational databases. The goal of the final stage of the project, which has just begun, is to develop a prototype system. Leaders of the project, however, describe it as one involving primarily basic and "pre-pre-competitive" research.[57] It is probably too soon to draw conclusions about the success, but it should be noted that foreign researchers have joined the project and fellowships are available to support work there.

"HYBRID" ORGANIZATIONS IN THE UNITED STATES

While there are no direct parallels to Japan's government-sponsored joint laboratories discussed above, hybrid organizations have been developed in the United States. Whereas in Japan the locus of activity is private sector corporations, in the United States universities form the core. Eighteen Engineering Research Centers (ERCs) have been established by the NSF to change the way that engineering research is done at U.S. universities.

Key features of the ERCs are their cross-disciplinary research and education with a systems orientation, technology transfer, and participation by industry. The ERCs focus on a range of technology areas that were not predetermined, but arose in the process of proposal review. Seven work on manufacturing and design, for example, three in microelectronics and optoelectronics, three in materials processing, two in biotechnology, and three in other areas related to energy and the environment. Due to limited funding (less than $40 million in 1989) and the large number of proposals, only a small fraction of proposals have been successful in receiving awards. The ERCs are funded on an incremental basis (in five year periods with interim third-year reviews), but a new proposal must be submitted after 11 years have passed.

The ERC is a partnership where the U.S. government (NSF) provides funding (half of the total), coordination, and oversight. The university provides the research and educational base, facilities, technology transfer mechanisms, and management. Industry contributes funding (about 30 percent of the total), along with advice and specialized expertise. Based on a subscription rate schedule, smaller companies pay less to participate. Participation by foreign companies in the ERCs is growing. The universities determine participation, but the general quid pro quo principle must be followed and the companies must open their doors to ERC researchers and students, as in the case of U.S. companies.

Examples of ERC impacts can be cited. Research at Lehigh University has enabled a member firm to become the first U.S. competitor with Japanese and German firms in producing welded wheel trucks for railroad cars. Carnegie Mellon University has developed a design system with General Motors that is being implemented in its Fisher Body Division. The ERCs also have had academic impacts in training graduate students in fields like optoelectronics engineering, in established cross department degrees, and new graduate curricula.

Interest in collaborative research has grown in recent years in the United States and there are a number of state and regional initiatives that involve government support. Sematech, a consortium that has recently been established with U.S. government funding, will involve private sector firms working on semiconductor manufacturing R&D. A history of concern about possible collusion among competing firms working together has acted to limit collaborative activities between U.S. government and industry. U.S. universities have instead been the locus of joint action here. Recent changes clarifying exemptions from antitrust law for joint R&D efforts and new thinking about the potential gains from joint approaches may well lead to new experimentation in the near future.

7

Conclusion

The many organizations that are neither purely academic nor purely industrial offer possibilities for expanding access through exchange of researchers and information. The pattern of the past, however, has been one of Japanese participation in and access to these organizations in the United States, but no similar experience for U.S. technical personnel with respect to Japan.

Because they are the targets of national government policy in both countries, national labs offer opportunities for increased exchange and collaboration under bilateral agreements such as the U.S.-Japan Agreement for Cooperation in Science and Technology. Because they are R&D organizations under the government's direct control, however, they can also become the objects of restrictive policies based on efforts to secure or maintain national technological leadership. Despite the gradual changes under way in U.S.-Japanese national lab cooperation, some believe the legacy of asymmetrical access, combined with increasing concerns about global competitiveness, may lead to restrictions on foreign access to the U.S. research environment or to a push toward indigenous technology development in Japan.

U.S. federal labs, except for those conducting classified research, have traditionally been open to foreign researchers. Last year Oak Ridge National Laboratory received 1,200 visitors from Japan and 64 Japanese scientists and engineers conducted research there. Of its 1,090 guest researchers last year, NIST hosted 432 from foreign countries; 32 of those were Japanese. This openness represents a significant investment on the part of U.S. labs. It is estimated that a U.S. staff scientist who hosts a full time visiting researcher must devote about 20 percent of his time to guiding that researcher's activities.[58]

In 1987, all of Japan's national labs together received only 543 foreign researchers.[59] Although ETL receives 1,200 foreign visitors each year, in fiscal year 1988, it had less than 40 foreign guest researchers.[60] Of the 26 accepted as of November 1988, five were from North America.[61] Japanese figures on national lab exchanges do not include large, national inter-university research institutes under the Ministry of Education, some of which receive numerous foreign researchers and conduct significant basic research. The National Laboratory for High Energy Physics (KEK), for example, received 325 foreign visitors in 1987, about 100 of whom stayed more than one month.[62] In comparison with the 64 Japanese visiting researchers to Oak Ridge, the U.S. lab sent only four to Japan.

The reasons for the disparity between the number of Japanese researchers in U.S. federal labs and the number of U.S. researchers in Japanese national labs are complex, including problems on both sides that extend beyond the policies of the laboratories. The career patterns of government researchers are different in the United States and Japan: Research abroad is generally seen to be more advantageous to a Japanese researcher's career than to that of his or her American counterpart. The shift in support for graduate education in the United States from grants to loans may also restrict the ability of young post-graduate researchers to go abroad. Research abroad is a luxury for a young U.S. researcher faced with a large student loan debt to be repaid. A number of other barriers have been noted, including expensive and inadequate housing in Japan, the language barrier, the lack of adequate accommodations for the education of foreign children, and a lack of experience in hosting foreign researchers from advanced industrial countries.

There are signs of change, however. Researchers at NIST report that they have good access to Japanese national labs, including those of MITI and NTT. The number of foreigners in Japanese national labs, while still small, has been increasing in recent years,[63] and recent changes in Japanese laws allow the employment of foreign researchers in Japanese national labs and universities. New fellowships specifically aimed at helping foreign researchers who want to work in Japanese national labs have also been established. As of October 1989, the NSF had awarded 22 STA fellowships. Although less than half of the slots administered by NSF have been filled, the number of U.S. postdoctoral researchers applying for and receiving these fellowships has been on the rise.

On the U.S. side, federal labs are also beginning to encourage their researchers to go to Japan, where there are good research opportunities. NIST and other U.S. labs offer Japanese language classes during working hours for interested researchers. There is also significant, ongoing collaboration between the United States and Japan through national labs. Oak Ridge National Laboratory, for example, is involved in collaborative research with Japan in areas such as new materials for fission energy, fusion development, nuclear fuel reprocessing, nuclear shielding, and nuclear physics.

In looking to the future, environmental and global issues offer "fertile ground" for additional collaboration. These include critically important areas that require complex, expensive, long-term, multidisciplinary research; examples are ozone depletion, globally distributed contaminants, erosion, desertification, ocean pollution, urbanization, biodiversity, deforestation, and resource depletion.

U.S. consulting organizations are becoming increasingly international. Some large U.S. not for profit consulting organizations have seen their contract research for Japanese clients grow, in terms of contract values, multiclient programs, and the joint commercialization of research results. Southwest Research Institute, for example, conducts research for Japanese clients in an array of engineering fields.

These trends can lead to challenges as well as opportunities, a major one being the question of whether consulting organizations will assume a significant role in a two-way transfer of science and technology, particularly from Japan to the United States. Working with foreign clients can lead to expanded personnel exchanges, an indispensable ingredient of technology transfer. The proprietary nature of much of the work of U.S. consulting organizations, however, requires that projects are compartmentalized and visitors escorted. U.S. consulting organizations will be increasingly challenged by potential conflicts between the internationalization of research and maintaining their lifeline of confidentiality. The internationalization of science and technology also highlights the need for translation of scientific materials in a timely manner. For some U.S. not for profit consulting organizations with ties to Japan, access to scientific information from Japanese companies is facilitated by physical visits to the Japanese location.

Although there have been isolated cases of restrictions on foreign attendance at meetings in recent years, professional associations may represent one of the most open avenues for international access to scientific and technological information. A few Japanese professional association journals, such as those of the JAST and the JSAP, are published in English, as are the results of some professional associations studies (eg., the JSPS study on rolling bearings). There is however, a considerable lag in receiving English language Japanese scientific and technical information, an indicator of the need for more, better, and faster translation. An important obstacle to U.S. access is the fact that Japanese professional association meetings are conducted in Japanese. U.S. researchers will need to make special efforts to learn more about the information that is exchanged at Japanese professional association meetings.

In view of the fact that Japan's national labs, professional associations, and "hybrid" organizations perform important roles in carrying out and disseminating the results of R&D useful to industry, these organizations offer unique opportunities for learning from Japan. In addition to the technology developed and adapted by these organizations, they are worthy of study from an organizational perspective. The "hybrid" organizations are still evolving, but they provide mechanisms to join efforts among competing private sector firms, a goal advocated by some in the United States today. While comparatively little attention has been paid to the professional associations in Japan, they are also actively involved in R&D projects useful to industry. "Professional associations" function somewhat differently in the United States and Japan, but these differences must be taken into account if they are to play a large role in international R&D collaboration.

Organizations that are not purely academic or industrial play important roles in the Japanese and American R&D systems, although those roles are often different. Some describe them as "bridging" organizations that provide links between basic research carried out primarily in universities and the more applied and proprietary research under way in private corporations; it is clear that they perform a wide array of other functions. It may be more accurate to view these organizations as islands in a river, with one bank formed by the university research facilities and the other bank by corporate laboratories. In this sense, the organizations that are neither *purely* academic nor industrial form important parts of a complex and dynamic R&D system in both countries. In addition to actually carrying out R&D, they in some cases help to set R&D priorities, diffuse technology domestically, and transfer technology internationally. Understanding these organizations better is a prerequisite for improving their effectiveness in two-way access to the R&D systems in the two countries.

Endnotes

1 National Science Foundation, *The Scientific and Technology Resources of Japan: A Comparison with the United States* (Washington, D.C.: June 1988), 53.

2 Kagaku Gijutsu Cho Gijutsu Seisaku Kyoku [Science and Technology Agency, Technology Policy Bureau], *Kagaku Gijutsu Yoran* [Science and Technology Survey], 1989, 52-53.

3 NTT is privately operated, however.

4 Somucho Tokei Kyoku [Management and Coordination Agency, Statistics Bureau], *Kagaku Gijutsu Kenkyu Hokoku* [Report on the Survey on Research and Development], 1987, 77, 81, 89.

5 See Science and Technology Survey, op. cit., 53.

6 By "government-owned" research institutions, we refer here to those which receive most of their funding from the national government, not including higher education institutions. It should be noted, however, that significant research and development is carried out in the United States with state and local government support. These organizations were not the subject of this meeting and are not covered in this report.

7 OECD, *The Changing Role of Government Research Laboratories* (Paris: 1989), 7.

8 There are a number of university-based facilities such as the Stanford Linear Accelerator Center in the United States and the National Laboratory for High Energy Physics (KEK) in Japan that are particularly active in basic research. They were subjects of discussion at the first bilateral meeting in this series and will not be dealt with here.

9 The JDA R&D budget (82 billion yen) made up almost one third of the total R&D budget for national laboratories in Japan in 1988. Masahiro Kawasaki, "Changing Role of National Laboratories in Japan," Keynote address, U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989. Some of this funding may be passed on in the form of contracts to others.

10 Agency for Industrial Science and Technology, Ministry of International Trade and Industry, *Symposium on Opportunities for US-Japan Science and Engineering Research Cooperation* (March 1989), 3. The budget for AIST including the headquarters was about $885 million. The labs accounted for $347 million. Throughout this paper, the following average yearly exchange rates are used: 1985: $1 = 238.54 yen; 1986: $1 = 168.52 yen; 1987: $1 = 144.64 yen; 1988: $1 = 128.2 yen.

11 See Richard J. Samuels, *Research Collaboration in Japan*, MIT Science and Technology Program, 1987, 39.

12 See Samuels, ibid., 40.

13 The exact number depends on how they are counted. U.S. Department of Commerce, *Directory of Federal Laboratory and Technologies Resources, 1988-1989* (Washington, D.C.: 1987); Office of Science and Technology Policy, *Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel*, Volume I-Summary Report, July 1984.

14 In the United States, the term "national laboratories" is usually used to refer to DOE's large, multipurpose government-owned contractor-operated labs. Other U.S. government laboratories are generally called "federal laboratories." For purposes of this paper, all U.S. government labs will be called "federal labs," to distinguish them from Japanese "national labs."

15 Science and Technology Agency, *National Laboratories and Research Public Corporations in Japan;* Kagaku Gijutsu Cho [Science and Technology Agency], *Zenkoku Shiken Kenkyu Kikan Meikan* [Directory of Japan's National Research Organizations], 1987-1988.

16 National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States* (Washington, D.C.: June 1988), 53.

17 Masahiro Kawasaki, "Changing Roles of National Laboratories in Japan," Keynote address, U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989; National Science Foundation, *National Patterns of Science and Technology Resources: 1987*, 39.

18 U.S. government R&D funding increased 33 percent between 1980 and 1985 in constant 1982 dollars; the comparative figure for Japan is 17 percent. National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States* (Washington, D.C.: June 1988), 52.

19 Kagaku Gijutsu Cho [Science and Technology Agency], *Kagaku Gijutsu Hakusho, 1988* [Science and Technology White Paper, 1988], 242.

20 While the U.S. DOE labs may not be representative of all U.S. labs in terms of organization and management, they nonetheless reflect general government policy toward the labs. The prevalence of examples from DOE labs in this paper is a reflection of the fact that some of the U.S.-Japan dialog participants were most familiar with those labs. DOE's large multipurpose labs represent a major segment of the U.S. federal labs. They include five energy labs—Argonne, Oak Ridge, Brookhaven, Berkeley, and Hanford—and three weapons labs—Los Alamos, Livermore, and Sandia.

21 Even during the 1960s, the Council recommended strengthening basic research. The recent controversy over Japan's modest performance in most areas of basic research indicates that this recommendation was not heeded.

22 Examples include the Bayh-Dole Act of 1980 (and subsequent amendments to it), The Stevenson-Wydler Technology Innovation Act of the same year, the Federal Technology Transfer Act of 1986, (which provided a legislative mandate for the Federal Laboratory Consortium for Technology Transfer), the 1987 Technology Innovation Act, and two Executive Orders, including the 1987 order on "Facilitating Access to Science and Technology."

23 Alexander Zucker, Keynote address, U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations," June 5-6, 1989.

24 Last year Oak Ridge National Laboratory issued 30 such patents. Lab representatives hold that these patents have been issued in areas in which U.S. industry is not involved, eg. ceramics processing and the development of new alloys.

25 "Government budget" refers to funds received from the ministry for joint research and development and does not include funds provided by industry participants.

26 Kagaku Gijutsu Cho [Science and Technology Agency], *Kagaku Gijutsu Hakusho, 1988* [Science and Technology White Paper, 1988], 85-86.

27 Kagaku Gijutsu Cho [Science and Technology Agency], *Kagaku Gijutsu Hakusho 1988* [Science and Technology White Paper, 1988], 43.

28 Science and Technology Agency, *Research Development Corporation of Japan*, 1986.

29 Research Development Corporation of Japan, *ERATO*, 2-3.

30 Michael K. Ozanian and Alexandra Ourusoff, "The FW International 500," *Financial World*, March 7-20, 1989, 86.

31 Iwao Toda, "An Overview of R&D Activities in NTT," U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

32 Carla Rapoport, "The World's Most Valuable Company," *Fortune*, Vol. 118, Oct. 18, 1988, 92.

33 "Privatization" of NTT is an ongoing process that continues to be the subject of great debate in Japan. See, for example, "Mei bakari no Mineika" [Privatization in Name Only], *Nihon Keizai*, May 5, 1989, 1.

34 As noted above, some of this funding may be passed to others in the form of contracts.

35 This figure includes the budget of the AIST headquarters.

36 NIST's total budget includes funds reimbursed from sources other than federal government appropriations. NIST's federal obligations for 1987 were $117,286,000.

37 Office of Science and Technology Policy, *Progress Report on Implementing the Recommendations of the White House Science Council's Federal Laboratory Review Panel*, Volume II — Status Report by Agencies, July 1984, 7-8. ETL's 1988 budget amounted to about 3.5 percent of the total of Japanese national labs' budgets that year. Estimates for the same year show that NIST (then the National Bureau of Standards, NBS) accounted for less than .2 percent of U.S. federal R&D obligations. National Science Foundation, *National Patterns of Science and Technology Resources: 1987*, 53.

38 The result has been an increase in the average age of national lab researchers to 42.8 years. Although some believe that a similar problem exists in the United States, comparable data are unavailable and some DOE studies have concluded that this is not a serious problem. Nor should it be assumed that older researchers are always less productive.

39 Ministry of International Trade and Industry, *Agency of Industrial Science and Technology*, 1988, 5.

40 The Franklin Institute has been disbanded.

41 These consulting firms note that although the financial value of the work they do is less than one percent of the nation's total R&D budget, they have served virtually every major industrial firm in the United States. The industrial clients of not for profit U.S. consulting organizations range from small to very large companies—both in the United States and abroad. On a dollar volume basis, however, service to large corporations predominates.

42 Southwest Research, for example, is able to conduct environmental technology development for the auto industry while simultaneously working with the Environmental Protection Agency to develop environmental standards because of circumscribed boundaries on each program that keep information compartmentalized. Battelle's policies are similar, prohibiting the organization from conducting the same research for two clients simultaneously.

43 Robert E. Schwerzel, "Battelle as a "Bridging" Organization: Some Specific Examples of Technology Transfer in Integrated Optics and Nonlinear Optics," U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

44 An example of U.S. private, not for profit work for the government is DOE's Pacific Northwest Laboratory (PNL), which is an operating division of Battelle.

45 Most professional associations are voluntary and open for membership, usually subject only to minor restrictions on age, experience, and education. There are, however, organizations such as the Japan Society for the Promotion of Science (JSPS) that are not membership organizations but nonetheless play an important role in bringing together scientists and engineers from various sectors and in promoting international scientific exchange. Most professional membership associations have membership dues that, coupled with subscription fees and conference attendance fees, support the organization. Institutional memberships or industrial company memberships, which some associations permit, commonly cost more than individual memberships. Membership size varies widely in both countries. The Institute of Electrical and Electronic Engineers has 300,000 members worldwide (240,000 in the United States). The American Chemical Society has about 137,000 members. The American Society of Mechanical Engineers has 119,000 members, including 19,000 students. The American Society for Engineering Education has about 10,000 members. The Japan Society of Mechanical Engineering has about 40,000 members. The Japan Society of Precision Engineering has 7,700 members. The Japan Society of Tribologists has 3,000 members.

46 The American Society of Civil Engineers, one of the oldest U.S. professional associations, was founded in 1852. The American Society of Mechanical Engineers was founded in 1880. The Japan Society of Mechanical Engineering, Japan's largest professional association, was established in 1897.

47 The Institute of Electrical and Electronic Engineers dates its history back to 1884.

48 The JSME-ASME agreement consists primarily of an exchange of the two societies' publications.

49 "Nihon Ryugakusha ni Joseikin" [Subsidies for Foreign Students], *Nihon Keizai*, March 25, 1989, 11.

50 Japan Society for the Promotion of Science, *JSPS Annual Report*, 1987-1988, 1.

51 J-TIES, Inc., "J-Ties," (College Park: Autumn, 1987), 2-3.

52 Toshio Sata, "Technology Transfer in Japanese Academic Societies and Engineering Associations" U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

53 The following discussion draws on remarks by Izuo Hayashi at the U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Laboratories and "Bridging" Organizations, June 5-6, 1989 and a paper on "Collaborative Research in Japan" by Izuo Hayashi, Masahiro Hirano, and Yoshifumi Katayama.

54 The Japan Key Technology Center was set up by MITI and the Ministry of Posts and Telecommunications with dividends from the sale of NTT stock. It acts as a kind of venture capitalist, providing 60-70 percent of the investment in projects with the rest of the capital from the participating companies who actually operate the projects independently of the government.

55 The project is scheduled to run for ten years. It involves 13 member companies and 25 researchers working at the joint lab.

56 See Hayashi, et. al., op. cit., 38.

57 Kazuhiro Fuchi, presentation on the Fifth Generation Computer Systems Project, U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Laboratories and "Bridging" Organizations, June 5-6, 1989.

58 Alexander Zucker, Keynote address, U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

59 Kagaku Gijutsu Cho [Science and Technology Agency], *Kagaku Gijutsu Hakusho, 1988*, [Science and Technology White Paper, 1988], 45.

60 Koichiro Tamura, "Role of the Electrotechnical Laboratory as a Public Service Organization," U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on National Labs and "Bridging" Organizations, June 5-6, 1989.

61 Ministry of International Trade and Industry, *Electrotechnical Laboratory*, 1989, 16.

62 Ken Kikuchi, "High Energy Physics in Japan," U.S.-Japan Dialog on Differences and Similarities in the Working Environment for Research, Workshop on University Research Labs, Jan. 9-10, 1989.

63 Japanese national research institutes received 543 foreign researchers in 1987, up from 217 in 1984. Kagaku Gijutsu Cho [Science and Technology Agency], *Kagaku Gijutsu Hakusho, 1988* [Science and Technology Agency White Paper, 1988], 45. There is no indication of the length of stay of these foreign researchers.

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